INVESTIGATING DRILL CONSTRAINT KINEMATICS IN MALE BASEBALL PITCHERS USING MARKERLESS MOTION CAPTURE

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This study investigated the kinematic differences that pitching constraint drills elicit compared to a baseball pitch. 18 male baseball pitchers with average height (183.7 ± 5.2cm), weight (87.4 ± 9.6kg), and skill level (Professional (4), Collegiate (5), High School (9)) were included. Video was recorded using a single camera from the open side. Each pitcher threw 3 maximum effort pitches from a mound. Next, 3 maximum effort throws were recorded for 8 different throwing drills: medicine ball hook'em drill, pivot pickoff drill, foot-up rocker drill, walk-in drill, towel drill, janitor drill, drop-step drill, and long toss. Videos were processed using pitchAI™, a markerless motion capture solution. The medicine ball hook'em drill was the most different to a pitch, and the towel drill was the most similar. This work demonstrates the first collective approach to studying the biomechanics of frequently used baseball pitching constraint drills.

KEYWORDS: BIOMECHANICS, CONSTRAINT DRILLS, PITCHING

INTRODUCTION: The goal of baseball pitching is to produce the highest velocities, greatest command of pitch location, and minimize the stress on the body. Pitching coaches and trainers accomplish this, through the implementation of drills and cues. Methods such as free throwing, long toss (Fleisig et al., 2011; Leafblad et al., 2019), weighted baseball and/or plyoball throwing (DeRenne & Syzmanski, 2009; Marsh et al., 2018; O'Connell et al., 2021), constraint drills (Wilk et al., 2002; Brady et al., 2020; Gray, 2020), and resistance training exercises (Newton & McEvoy, 1994; Wilk et al., 2002) have been thoroughly explored in research.

Through the ecological dynamics approach to skill acquisition, coaches implement a variety of appropriate constraints to help facilitate the search for successful movement solutions (Renshaw et al., 2010). It has been recommended that sport research needs to integrate biomechanics and motor learning better to truly advance knowledge in the area (Glazier & Davids, 2009), and baseball is no exception. There has only been limited effort to achieve this, in part due to the previous technological limitations of motion capture technology (Bristow et al., 2019; Dobos et al., 2022; Gustafson et al., 2022).

This research aims to determine the specific kinematic differences that common pitching constraint drills elicit compared to a typical baseball pitch using markerless motion capture. We hypothesize that each constraint drill will demonstrate unique kinematic characteristics relative to regular pitches.

METHODS: Participants were unaware of the study hypothesis. All participants were in their offseason training and underwent a standardized evaluation. In each case, the dominant extremity throwing pattern was examined. Ethics approval was obtained from a university research ethics board. Following a typical warmup for a maximum effort throwing day, 18 male baseball pitchers had video recorded while throwing. 3 throws at maximum effort (100%) for regulation pitches and 8 different constraint drills (Figure 1). Pitches were captured first, followed by the constraint drills in a randomized order. Open side video (sampled at 240 Hz, 1080p) was recorded using an iPhone 13Pro for each throw, and time series kinematic data were generated using pitchAI^{TM} (Dobos et al., 2022). Briefly, pitchAI^{TM} (3MotionAI, Oakville, ON) is a single camera pose estimation motion capture solution, that automatically tracks 19 joint centres, processes the kinematics and outputs time series kinematic data (Dobos et al., 2022). The metrics investigated were selected from those previously reported in the literature to have the greatest effects on velocity and efficiency and were broken down into 2 subcategories: average postures (joint angles at the time points of foot plant, maximum external rotation, and ball release) and maximum postures (greatest joint angles achieved from select metrics, regardless of timepoint). Descriptive analysis was performed at time points of foot plant, maximal shoulder external rotation, and ball release using Microsoft Excel.

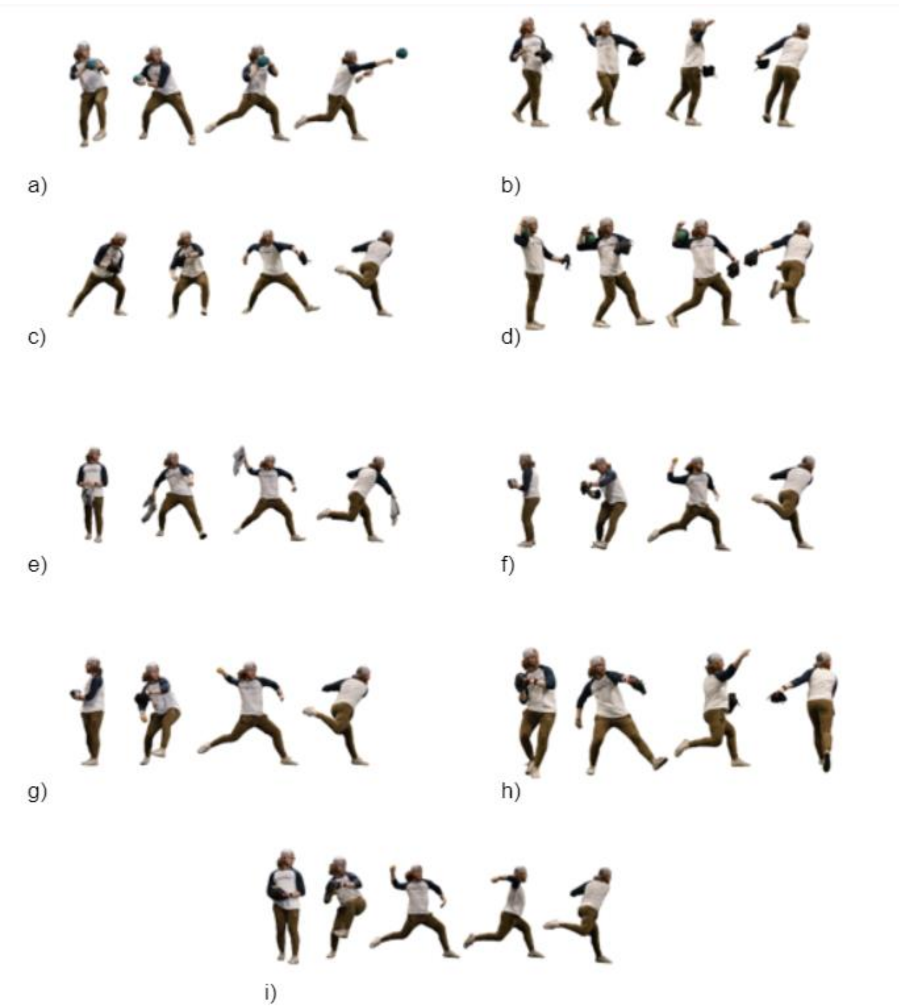

Figure 1. A visual breakdown of each critical feature for the 8 different constraint drills and pitches. a) medicine ball hook'em drill; b) pivot pickoff drill; c) foot-up rocker drill; d) walk-in drill; e) towel drill; f) drop-step drill; g) janitor drill; h) long-toss drill; i) regulation throw.

RESULTS: Outliers were removed if they failed a quality flagging metric as calculated by pitchAI^{TM}. This metric was based off the normality of data as per a pitching delivery, and those more than three SD from normal were flagged. Data from 18 pitchers were included in this study. Demographic information including height (183.7 ± 5.2cm), weight (87.4 ± 9.6kg), and skill level (Professional (4), Collegiate (5), or High School (9)) were recorded. Maximum joint angles for maximum effort pitches and constraint drills can be found in Table 1. Average joint angles can be found in Table 2. In the tables, maximum and average joint angles (degrees) for maximum effort pitches are displayed on the top row. The difference between maximum effort pitch and constraint drill kinematics (degrees) are presented for each drill.

Table 1: Maximum joint angles (degrees) for maximum effort pitches and constraint drill difference (degrees) from maximum pitch (positive value means drill was greater than mound).

	Maximum Joint Angle			
	Stride Length	Maximum Shoulder External Rotation	Maximum Hip-Shoulder Separation	Maximum Shoulder Horizontal Abduction
Pitch Max	**89±5.3**	**161.2±11.7**	**30±3.1**	**47.1±7.1**
Medicine Ball Max	-31.5±10.6	-77.9±15.9	-22.8±9	-35.6±23.1
Pivot Pickoff Max	-58.1±5.3	-37.7±48.3	-14±8.9	-70.7±14.3
Towel Drill Max	0±4.7	-7.1±14.3	-2.2±3.2	0.6±7.7
Foot-up Max	-15.4±13.3	-4.7±15.4	-13.6±9.3	-27.9±15.2
Walk-in Max	-29.8±15.4	-7.6±23	-12.4±9.6	-28.5±8.9
Janitor Max	-26.1±13	-10.4±20.4	-15.3±11	-26.1±20.4
Drop-step Max	-31.7±10.6	-24.8±33.4	-19.4±9.9	-36.8±9.6
Long Toss Max	-21.4±8.4	-16.1±22.9	-9.5±8.2	-26.4±11.6

Table 2: Average joint angles (degrees) for maximum effort pitches and constraint drill difference (degrees) from maximum pitch (positive value means drill was greater than mound). FP = Foot Plant; MER = Maximum External Rotation; BR = Ball Release.

	Average Joint Angle						
	Elbow Flexion at FP	Shoulder Horizontal Abduction at FP	Shoulder Abduction at FP	Shoulder External Rotation at FP	Trunk Rotation at FP	Trunk Rotation at MER	Lead Knee Extension at BR
Pitch Max	**95.5±14.4**	**30.3±8.6**	**85.6±10.3**	**80.7±25.1**	**24.5±14.8**	**80.4±7.6**	**104.5±6.4**
Medicine Ball Max	24.2±19.5	-36.9±15.4	-30.4±5.8	-43.4±15.5	-26.8±15.8	-15.8±30.8	-16±6.1
Pivot Pickoff Max	2.6±20.9	-82.4±12.9	-13.4±20.8	-46.3±35.8	-31.9±18.3	-53.4±39.4	16±13.7
Towel Drill Max	-0.7±11.4	-2.4±7.1	-0.2±8.5	6.6±19.4	5.2±11.1	2.5±7.3	-1.9±5.9
Foot-up Max	-7.7±10.7	-28.8±20.5	-2.6±11.8	17.6±39	1±28.4	-5.8±12.3	-2.8±6.8
Walk-in Max	5.1±10.7	-40.8±22.3	-10.9±12.4	-14.5±30.5	-25.8±26.6	-1.9±8.5	-0.6±6
Janitor Max	-2.1±13.5	-34.2±22.3	-5.1±8.5	2.9±32.4	-14.2±27.2	-9.5±24	-1.3±6.4
Drop-step Max	-9.7±12.6	-43.1±13.7	-8.1±9.6	11±31.1	-7.5±24	-16.3±22.3	0.9±6.7
Long Toss Max	-12.8±9.9	-26.8±14.9	-6.9±14.5	8.5±38.4	-2.8±22.3	-11.2±12.3	0.6±5.6

DISCUSSION: This is the first study to quantify the kinematics of several pitching constraint drills, in addition to recreating data on drills that have already been studied. While advanced statistical testing is still required to confirm these findings, this descriptive analysis provides a framework for further investigation. Our findings indicate constraint drills demonstrated unique kinematic features for individual pitchers. The medicine ball hook'em drill attempts to target improved hip-shoulder separation and improved "lead leg blocking" in players. Our data suggests the opposite, with slightly more lead leg flexion at ball release and reduced maximum hip-shoulder separation. The towel drill is used to replicate the baseball throwing motion, and it did so - demonstrating the least overall amount of variation compared to other constraint drills. Considering the goal of most constraint drills is to positively influence throwing mechanics, the towel drill is unlikely to create enough of a novel stimulus to drive positive change and is thus not likely to be recommended as a drill of choice. The foot-up rocker drill is used to constrain the lower half and improve rear leg loading. This constraint drill showed greater shoulder external rotation at foot plant, and overall reduced shoulder horizontal abduction throughout the throw. The walk-in is primarily used to improve trunk rotation and arm action, which is achieved by decreasing torso rotation by 25.8 degrees. The janitor is designed to improve general sequencing and torso anti-rotation, which it appeared to do with reduced shoulder horizontal abduction and reduced torso rotation at foot plant. The Drop-step featured reduced torso rotation at foot plant and maximum external rotation, suggesting that it helped delay trunk rotation. Long toss is used heavily in youth baseball, and in most warmup throwing programs. The key kinematic features of long toss included reduced scapular retraction at foot plant, and earlier shoulder external rotation at foot plant. The principal limitations of this study were the labeling of foot plant and the variation in drill technique between participants. Throughout the testing session, participants received the same drill instructions, although there were tiny changes in technique that are not under instruction's control and were permitted as they reflect real life individual differences between drills.

CONCLUSION: Organizations, teams, and coaches have long been training their players with throwing constraint drills to improve pitch velocity and efficiency. Prior to this investigation, little empirical research investigating the biomechanical features of throwing constraint drills exists. This work demonstrates the first collective approach to studying the biomechanics of common constraint drills, in which coaches can refer to when choosing appropriate drills for their players.

REFERENCES:

Brady, A., Briend, S., Caravan, A., Lindley, K., O'Connell, M., Gowdey, G., & Boddy, K. (2020). A Kinematic and Kinetic Comparison of Mound and Rocker Throws.Bristow, E., Caravan, A., Boddy, K., Briend, S., & O'Connell, M. E. (2019). Arm Stress Comparisons Between Common Baseball Pitch Types.DeRenne, C., & Szymanski, D. J. (2009). Effects of baseball weighted implement training: a brief review. Strength & Conditioning Journal, 31(2), 30-37.Dobos, T. J., Bench, R. W., McKinnon, C. D., Brady, A., Boddy, K. J., Holmes, M. W., & Sonne, M. W. (2022). Validation of pitchAITM markerless motion capture using marker-based 3D motion capture. Sports Biomechanics, 1-21.

Fleisig, G. S., Bolt, B., Fortenbaugh, D., Wilk, K. E., & Andrews, J. R. (2011). Biomechanical comparison of baseball pitching and long-toss: implications for training and rehabilitation. Journal of orthopaedic & sports physical therapy, 41(5), 296-303.Glazier, P. S., & Davids, K. (2009). Constraints on the complete optimization of human motion. Sports Medicine, 39(1), 15-28.Gray, R. (2020). Comparing the constraints led approach, differential learning and prescriptive instruction for training opposite-field hitting in baseball. Psychology of Sport and Exercise, 51, 101797.

Gustafson, J. A., Dowling, B., Heidloff, D., Quigley, R. J., & Garrigues, G. E. (2022). Optimizing Pitching Performance through Shoulder and Elbow Biomechanics. Operative Techniques in Sports Medicine, 150890.Leafblad, N. D., Larson, D. R., Fleisig, G. S., Conte, S., Fealy, S. A., Dines, J. S., ... & Camp, C. L. (2019). Variability in baseball throwing metrics during a structured long-toss program: does one size fit all or should programs be individualized?. Sports health, 11(6), 535-542.Marsh, J. A., Wagshol, M. I., Boddy, K. J., O'Connell, M. E., Briend, S. J., Lindley, K. E., & Caravan, A. (2018). Effects of a six-week weighted-implement throwing program on baseball pitching velocity, kinematics, arm stress, and arm range of motion. PeerJ, 6, e6003.Newton, R. U., & McEvoy, K. P. (1994). Baseball throwing velocity: A comparison of medicine ball training and weight training. J Strength Cond Res, 8(3), 198-203.O'Connell, M., Lindley, K., Scheffey, J., Caravan, A., Marsh, J., & Brady, A. (2021). Weighted baseball training affects arm speed without increasing elbow and shoulder joint kinetics.Renshaw, I., Chow, J. Y., Davids, K., & Hammond, J. (2010). A constraints-led perspective to understanding skill acquisition and game play: a basis for integration of motor learning theory and physical education praxis?. Physical Education and Sport Pedagogy, 15(2), 117-137.Wilk, K. E., Meister, K., & Andrews, J. R. (2002). Current concepts in the rehabilitation of the overhead throwing athlete. The American journal of sports medicine, 30(1), 136-151.